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Efficiency of Fertilizer Topdressings on Alfalfa

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CONTENTS

MATERIALS AND METHODS 4

EXPERIMENTAL RESULTS 6

- Yield Response to P and K 6
- Percent of P and K in Hay 8
- Yield of P and K 8
- Phosphorus Uptake From Topdressings 14

TRENDS IN SOIL TEST VALUES 15

DISCUSSION 18

SUMMARY AND CONCLUSIONS 21

LITERATURE CITED 22

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When phosphorus (P) and potassium (K) deficiencies occur in established alfalfa, topdressings with carriers of these nutrients are recommended. Studies on the efficiency of fertilizer applied to the soil surface without incorporation into the soil are lacking in Illinois. When fertilizer is applied on the soil surface the question arises whether the alfalfa plant can efficiently absorb it, since P and K move very slowly into the soil and the soil surface is dry much of the time.

Phosphorus uptake by alfalfa from topdressings was studied by Lawton et al. (1953), Hanway et al. (1953), and Woodhouse (1956). In each study it was found that alfalfa efficiently utilized P placed on or near the soil surface. Terman et al. (1960) found that alfalfa yields were higher the first year of production following heavy initial broadcast applications of P than after smaller annual topdressings. In subsequent years, yields following the heavy initial applications became progressively lower compared with yields after smaller annual topdressings. Hanway et al. (1953), working with a soil low in available P and K, obtained large yield increases from P and K applications. The recovery of topdressed P was considered very efficient and the apparent recovery of applied K was as high as 100 percent following several treatments.

Stivers (1952) stated, "No relation was found to exist between stand maintenance and P fertilization or phosphorus content. Also, no consistent relationship between yield and potassium content of alfalfa was found." Markus and Battle (1965) observed that the P content varied with weather conditions. Likewise, Kresge and Younts (1962) stated, "The critical K level (that percent in harvested forage below which a significant [yield] decrease from the maximum occurs) varied throughout the growing season with a peak in mid-summer." He found that the most efficient use of applied K was from a combination of an early spring application with another application after the first cutting.

Markus and Battle (1965) observed that yield response to P and K depended upon the supplying power of the soil for these nutrients. The soil in their study supplied about 17 pounds of P per acre to alfalfa where no P fertilizer was applied. This was adequate to meet the needs of the crop, and there was no response to applied P. Where fertilizer P was not applied a depletion of available soil P occurred and this suggested that without applications of P, the P fertility of the soil would be reduced. On the other hand, the soil supplied about 38 pounds of K per acre, which was insufficient for continued alfalfa production, and there was a marked response to K applications.

The soils at the Northeastern Illinois Research Center, Elwood, Illinois are deficient in P, and while soil tests frequently are medium to high for K, response to applications of K are reported, but have not been previously confirmed by research.

Materials and Methods

The experiment was located on a Blount silt loam. Initial pH of the soil was 5.2, and four tons per acre of agricultural lime was applied and disked into the soil after plowing. Soil samples were taken from each plot after liming and before application of P or K fertilizers. Soil test results were as follows:

	Average	**Range**
pH	6.0	5.3-6.5
P_1, lb. per acre	11	7-18
K, lb. per acre	222	170-300+

An application of 0-20-20 at 200 pounds per acre was made to three of four replications to aid in getting a stand established. Concentrated superphosphate and muriate of potash were fertilizer sources for P and K variables. The seedbed was double-disked and 15 pounds per acre of Vernal alfalfa was seeded with a cultipacker-type seeder on August 8, 1962.

Each time fertilizer was applied in the experiment, four adjacent plots (constituting a main plot) in each replication were treated as follows: one received no fertilizer, one received P only, another received K only, and another received both P and K. The treatments were as follows:

1. Fertilizer incorporated into the seedbed. Rates — P, 132 pounds per acre; K, 747 pounds per acre.
2. Fertilizer incorporated into the seedbed. Rates — P, 264 pounds per acre; K, 747 pounds per acre.
3. Phosphorus topdressed the spring after planting. Potassium, one-half topdressed in the spring after planting and one-half topdressed after two years of production. Rates — P, 132 pounds per acre; K, 747 pounds per acre.
4. Fertilizer topdressed before growth each spring, 1963 through 1966. Rates — P, 33 pounds per acre; K, 187 pounds per acre annually.
5. Fertilizer topdressed after first cutting each year, 1963 through 1966. Rates — P, 33 pounds per acre; K, 187 pounds per acre annually.
6. Fertilizer topdressed before growth each spring, 1963 through 1966. Rates — P, 16.5 pounds per acre; K, 93.5 pounds per acre annually.
7. Fertilizer topdressed after third cutting each year, 1963 through 1966. Rates — P, 33 pounds per acre; K, 187 pounds per acre annually.

Comparisons were made among treatments as follows:

1 vs. 2 — Rate of fertilizer incorporated.
1 vs. 3 — Incorporation of fertilizer vs. topdressing.
3 vs. 4 — Four-year topdressing vs. four annual topdressings.

4 vs. 5 — Spring vs. summer topdressing.
4 vs. 7 — Spring vs. fall topdressing.
4 vs. 6 — Rate of fertilizer topdressed.

The fertilizer subplots were 10 feet by 25 feet and main plots were 40 feet by 25 feet. Four replications of main plots were in a randomized complete-block design and subplots were randomized within main plots. A strip 38 or 40 inches wide and 20 feet to 24 feet long was harvested three times each year from 1963 through 1969. At the time of each cutting, 1963 through 1966, at least 20 stems were taken at random from each plot and analyzed for P and K. Soil samples consisting of three soil cores approximately 6 inches deep were taken after each cutting from plots receiving treatments 1 and 2 where fertilizer had been incorporated during seedbed preparation. Samples were analyzed for P, K, and pH in the soil testing laboratory.

Soil pH was measured in a thin soil paste (prepared with water) with a pH meter. Available soil P was determined according to the procedure of Bray as reported by Laverty (1963). Exchangeable soil potassium was extracted with 1 *N* ammonium acetate buffered at pH 7 (1:10, soil: solution ratio) and determined with a flame photometer. Plant phosphorus was determined with the vanadomolybdate method following wet ashing with periodic-perchloric acid digestion (Smith, 1965). Plant potassium was determined with a flame photometer on an ammonium acetate extract of the tissue (Jackson, 1958). All analyses were made in the Agronomy Department laboratories using techniques modified for rapid routine processing of samples.

Experimental results for the periods 1963 through 1966 and 1967 through 1969 will be considered separately. Fertilizer applications were made only in the first four years, and all differences observed in the last three years were caused by the residual effects of previous treatments. The comparison between incorporation of fertilizer (treatment 1) and topdressing (treatment 3) is not entirely valid, particularly in the case of K. The original plans called for all of the K in treatment 3 to be topdressed in the spring after establishment. However, it was observed in treatments 1 and 2, where K was applied at 747 pounds per acre and incorporated into the soil, that germination percentage and seedling vigor were reduced. For this reason it was decided that 374 pounds per acre would be topdressed during the first production year and a second application of 374 pounds per acre would be made in the third production year. The first application of fertilizer in treatment 7 was not made until after the third cutting in the first year of production, so there were no effects of fertilizer in the first year's production on these plots.

Experimental Results

Yield Response to P and K

In the first four-year period there was a consistent positive yield response to P (Table 1). For the four-year period, 1963 through 1966, plots that received P produced an average of 18.0 tons per acre and plots receiving no P produced an average of only 14.2 tons per acre.

Table 1. — Alfalfa Hay Yields Following Application of P and K at Different Times and Rates of Application at Elwood, Illinois, 1963 Through 1966

Rate, time, and method of application	Year	None	P	K	PK	Effect of fertilizer[a]	
						+P	+K
				(Tons per acre)			
1. P, 132 lb./acre	1	3.12	4.66	2.09	3.82	+1.64	− .94
K, 747 lb./acre	2	3.21	3.94	2.78	3.71	+ .83	− .33
(Incorporated into	3	3.41	4.54	3.78	4.48	+ .92	+ .16
the seedbed)	4	3.99	5.21	4.64	5.70	+1.14	+ .57
	Total	13.73	18.35	13.29	17.71	+4.53	− .54
2. P, 264 lb./acre	1	2.82	4.61	1.72	4.02	+2.04	− .84
K, 747 lb./acre	2	3.26	4.21	2.67	3.73	+1.00	− .54
(Incorporated into	3	3.54	4.91	3.79	4.90	+1.24	+ .12
the seedbed)	4	4.20	5.06	4.53	5.60	+ .96	+ .44
	Total	13.82	18.79	12.71	18.25	+5.24	− .82
3. P, 132 lb./acre	1	2.79	3.90	2.80	3.51	+ .91	− .19
K, 374 lb./acre[b]	2	3.47	4.23	3.62	4.49	+ .82	+ .20
(Topdressed in	3	3.46	4.88	3.94	5.16	+1.32	+ .38
spring after	4	3.66	4.72	4.99	5.44	+ .76	+1.02
seeding)	Total	13.38	17.73	15.35	18.60	+3.81	+1.42
4. P, 33 lb./acre	1	3.21	3.38	3.22	3.86	+ .40	+ .25
K, 187 lb./acre	2	3.44	4.07	3.62	4.26	+ .64	+ .18
(Topdressed before	3	3.63	4.72	3.74	5.25	+1.30	+ .32
growth each	4	4.16	5.25	4.51	5.83	+1.20	+ .46
spring)	Total	14.44	17.42	15.09	19.20	+3.54	+1.22
5. P, 33 lb./acre	1	3.04	3.02	2.45	3.00	+ .26	− .30
K, 187 lb./acre	2	3.42	4.57	3.34	4.48	+1.15	− .08
(Topdressed after	3	3.41	4.97	3.68	4.94	+1.41	+ .12
first cut each	4	4.05	5.25	4.74	5.82	+1.14	+ .63
year)	Total	13.92	17.81	14.21	18.24	+3.96	+ .36
6. P, 16.5 lb./acre	1	3.08	3.39	3.15	3.38	+ .27	+ .03
K, 93.5 lb./acre	2	3.36	3.86	3.34	4.06	+ .61	+ .09
(Topdressed before	3	3.38	4.38	3.67	4.72	+1.02	+ .32
growth each	4	4.25	5.12	4.43	5.64	+1.04	+ .35
spring)	Total	14.07	16.75	14.59	17.80	+2.94	+ .78
7. P, 33 lb./acre	1	3.14	3.40	3.22	3.17	+ .10	− .08
K, 187 lb./acre	2	3.60	4.09	3.62	4.44	+ .66	+ .18
(Topdressed after	3	3.79	4.82	3.98	4.99	+1.02	+ .18
last cut each	4	4.24	5.36	4.48	5.67	+1.16	+ .28
year)	Total	14.77	17.67	15.30	18.27	+2.94	+ .56

[a] For example, the effect of P on alfalfa yield was calculated as follows:

$$\frac{(4.66 + 3.82) - (3.12 + 2.09)}{2} = 1.64.$$

[b] A second application of K, 374 pounds per acre, was made in the spring of 1965, the third year of production.

Yields in the second period, 1967 through 1969, are given in Table 2. Plots that had received P produced 11.8 tons per acre and plots receiving no P produced 9.7 tons per acre. Yield differences required for significance between times and methods of application are given in Table 14. None of the comparisons previously specified for this phase of the study were statistically significant. However, some observed differences, though not statistically significant, are of interest. Over the initial four-year period, yields from plots receiving 264 pounds per acre of incorporated

Table 2. — Effect of Previous Fertilizer Treatments Upon Alfalfa Hay Yields, 1967 Through 1969

Rate, time, and method of application	Year	None	P	K	PK	Effect of fertilizer	
						+P	+K
				(Tons per acre)			
1. P, 132 lb./acre	5	4.20	5.33	4.70	5.72	+1.08	+ .44
K, 747 lb./acre	6	2.71	3.37	3.15	3.62	+ .56	+ .34
(Incorporated	7	3.14	3.62	3.22	3.69	+ .48	+ .08
into seedbed)	Total	10.05	12.32	11.07	13.03	+2.12	+ .86
2. P, 264 lb./acre	5	4.33	5.47	4.33	5.78	+1.30	+ .16
K, 747 lb./acre	6	2.79	3.16	2.89	3.47	+ .48	+ .20
(Incorporated	7	3.24	3.51	3.10	4.12	+ .64	+ .24
into seedbed)	Total	10.36	12.14	10.32	13.37	+2.42	+ .60
3. P, 132 lb./acre	5	3.94	4.83	4.60	5.37	+ .83	+ .60
K, 374 lb./acre[a]	6	2.15	2.15	2.45	2.88	+ .22	+ .52
(Topdressed in	7	2.29	2.39	2.84	3.30	+ .28	+ .73
spring after seeding)	Total	8.38	9.37	9.89	11.55	+1.33	+1.85
4. P, 33 lb./acre	5	4.17	5.29	4.29	5.93	+1.38	+ .38
K, 187 lb./acre	6	2.39	2.77	2.13	3.32	+ .78	+ .14
(Topdressed before	7	2.80	2.97	2.58	3.60	+ .60	+ .20
growth each spring)	Total	9.36	11.03	9.00	12.85	+2.76	+ .72
5. P, 33 lb./acre	5	4.15	5.32	4.45	5.89	+1.30	+ .44
K, 187 lb./acre	6	2.24	2.61	2.57	3.25	+ .52	+ .48
(Topdressed after	7	2.66	2.48	3.15	3.48	+ .08	+ .74
first cut each year)	Total	9.05	10.41	10.17	12.62	+1.90	+1.66
6. P, 16.5 lb./acre	5	4.12	4.87	4.28	5.39	+ .93	+ .34
K, 93.5 lb./acre	6	2.25	2.16	2.29	2.75	+ .18	+ .32
(Topdressed before	7	2.67	2.36	2.74	2.83	− .11	+ .27
growth each spring)	Total	9.04	9.39	9.31	10.97	+1.00	+ .93
7. P, 33 lb./acre	5	4.20	5.60	4.62	6.20	+1.49	+ .51
K, 187 lb./acre	6	2.15	3.29	2.88	3.70	+ .98	+ .57
(Topdressed after	7	2.72	3.58	3.17	3.85	+ .77	+ .36
last cut each year)	Total	9.07	12.47	10.67	13.75	+3.24	+1.44

[a] A second application of K, 374 pounds per acre, was made in the spring of 1965, the third year of production.

P were 0.71 ton per acre greater than those receiving 132 pounds per acre. Yields from plots receiving 132 pounds per acre of incorporated P were 0.72 ton per acre greater than those receiving the same amount topdressed. Differences in response to topdressed P among plots were very small except at low rates, 16.5 vs. 33.0 pounds per acre applied each spring. Response was 0.60 ton per acre more from plots receiving 33.0 pounds per acre of P. Phosphorus applications incorporated into the seedbed appeared to be somewhat more efficient than fertilizer topdressed on existing stands. Response to P topdressings were relatively large, but time of application did not appear to be important.

The yield response to K (Table 1) was less consistent than to P. As noted above, incorporation of 747 pounds per acre of K into the seedbed reduced stand and vigor of seedlings, and resulted in an average yield reduction of 0.68 ton per acre in the first two years of production. Where K fertilizer was topdressed, there was little or no response, 0.06 ton per acre, in the same two-year period. All K treatments showed a positive response, an average of 0.76 ton per acre in the third and fourth years of production. The total residual response in the fifth, sixth, and seventh years (Table 2) of production was 1.12 tons per acre. Responses to K topdressed at various times did not vary significantly.

Percent of P and K in Hay

The P and K composition of the hay as a percentage of dry-matter yield produced in 1966, the fourth year of production, is given in Tables 3 and 4, respectively. In this particular year, the concentration of P was highest in the first cutting, intermediate in the second cutting, and lowest in the third cutting. The percent of K in the first cutting was also highest, but concentration in the third cutting was higher than in the second. The average composition of each nutrient varied widely among cuttings, 0.16 to 0.25 percent for P and 1.45 to 2.06 percent for K. In fact, the ranges in P composition of the treated and untreated plots failed to overlap in the first and third cuttings. The ranges were 0.21 to 0.29 percent and 0.13 to 0.18 percent in the first and third cuttings respectively. There was only a slight overlapping in ranges of K, 1.61 to 2.52 percent and 1.22 to 1.69 percent in the first and second cuttings respectively.

Yield of P and K

Amounts of P and K removed in hay during the first four-year period are given in Tables 5 and 6. In plots receiving no fertilizer, 8.4, 10.5, 9.6, and 12.5 pounds per acre of P were removed in hay in 1963, 1964,

Table 3. — Percent Phosphorus in Alfalfa Hay in the Fourth Year of Production From Plots Which Had P and K Applied at Various Times in 1966

Treatment	Cutting	None	P	K	PK	Effect of fertilizer	
						+P	+K
			(Percent of dry matter)				
1. P, 132 lb./acre	1	.22	.28	.20	.27	+.06	−.02
K, 747 lb./acre	2	.15	.20	.16	.19	+.04	.00
(Incorporated into seedbed)	3	.13	.18	.14	.18	+.04	.00
2. P, 264 lb./acre	1	.20	.30	.20	.31	+.10	.00
K, 747 lb./acre	2	.16	.22	.16	.22	+.06	.00
(Incorporated into seedbed)	3	.13	.20	.13	.19	+.06	.00
3. P, 132 lb./acre	1	.21	.26	.20	.27	+.06	.00
K, 374 lb./acre	2	.16	.22	.18	.21	+.04	.00
(Topdressed in spring after seeding)	3	.12	.16	.14	.17	+.04	+.02
4. P, 33 lb./acre	1	.25	.30	.19	.31	+.08	−.03
K, 187 lb./acre	2	.16	.22	.14	.19	+.06	−.03
(Topdressed before growth each spring)	3	.14	.18	.14	.18	+.04	.00
5. P, 33 lb./acre	1	.22	.31	.20	.30	+.10	−.02
K, 187 lb./acre	2	.16	.24	.15	.20	+.06	−.02
(Topdressed after first cut each year)	3	.13	.20	.14	.20	+.06	.00
6. P, 16.5 lb./acre	1	.20	.29	.19	.30	+.10	.00
K, 93.5 lb./acre	2	.16	.20	.14	.18	+.04	−.02
(Topdressed before growth each spring)	3	.13	.17	.14	.14	+.02	−.01
7. P, 33 lb./acre	1	.24	.32	.20	.27	+.08	−.05
K, 187 lb./acre	2	.16	.22	.16	.21	+.06	.00
(Topdressed after last cut each year)	3	.12	.19	.13	.16	+.05	−.01

[a] A second application of K, 374 pounds per acre, was made in the spring of 1965, the third year of production.

1965, and 1966 respectively. Similarly, amounts of K removed in hay in each of the years were 101, 118, 110, and 111 pounds per acre. It is obvious that even though there was a response to P each year and to K after the second year of production, the soil had the ability to supply considerable amounts of nutrients, and these amounts did not diminish with continued removal. Application of P increased the amount of P in hay in the four-year period by 20 pounds per acre. The application of K increased the amount of K in the hay by 214 pounds per acre. Phos-

Table 4. — Percent Potassium in Alfalfa in the Fourth Harvest Year From Plots Which Had P and K Applied at Various Times in 1966

Treatment	Cutting	None	P	K	PK	Effect of fertilizer	
						+P	+K
			(Percent of dry matter)				
1. P, 132 lb./acre	1	1.81	1.51	2.38	2.29	−.20	+ .68
K, 747 lb./acre	2	1.40	1.12	1.70	1.66	−.16	+ .42
(Incorporated into the seedbed)	3	1.60	1.38	2.07	1.86	−.22	+ .48
2. P, 264 lb./acre	1	1.86	1.38	2.64	2.11	−.50	+ .76
K, 747 lb./acre	2	1.48	1.24	1.71	1.54	−.20	+ .26
(Incorporated into the seedbed)	3	1.55	1.39	2.01	1.70	−.24	+ .38
3. P, 132 lb./acre	1	1.72	1.31	2.98	2.67	−.36	+1.31
K, 374 lb./acre[a]	2	1.22	.98	1.68	1.58	−.17	+ .53
(Topdressed in spring after seeding)	3	1.58	1.42	2.26	1.94	−.24	+ .60
4. P, 33 lb./acre	1	1.62	1.46	2.52	2.62	−.03	+1.03
K, 187 lb./acre	2	1.20	1.35	1.79	1.78	+.07	+ .51
(Topdressed before growth each spring)	3	1.40	1.33	2.26	2.20	−.06	+ .86
5. P, 33 lb./acre	1	1.76	1.52	2.84	2.57	−.25	+1.06
K, 187 lb./acre	2	1.30	1.15	2.07	1.86	−.18	+ .74
(Topdressed after first cut each year)	3	1.62	1.31	2.24	1.93	−.31	+ .62
6. P, 16.5 lb./acre	1	1.82	1.37	2.32	2.45	−.16	+ .79
K, 93.5 lb./acre	2	1.25	1.11	1.58	1.54	−.09	+ .38
(Topdressed before growth each spring)	3	1.74	1.45	1.97	1.78	−.24	+ .28
7. P, 33 lb./acre	1	2.00	1.36	2.61	2.31	−.47	+ .78
K, 187 lb./acre	2	1.21	1.00	1.68	1.53	−.18	+ .50
(Topdressed after last cut each year)	3	1.67	1.22	1.99	1.77	−.34	+ .44

[a] A second application of K, 374 pounds per acre, was made in the spring of 1965, the third year of production.

phorus applications increased the total K removed in hay 106 pounds per acre, even though the percent of K was slightly reduced by applications of P. On the other hand, applications of K had little influence on the amount of P removed in the hay where K was topdressed.

Time and method of application did not have much effect on the amount of P removed in the crop. There was 12.0 pounds per acre more P removed where 264 pounds per acre of P was incorporated into the soil compared with the 132-pound-per-acre rate of P. At the 33-

Table 5. — Phosphorus, Pounds per Acre, in Alfalfa Hay Following Application of P and K at Different Times and Rates at Elwood, Illinois, 1963 Through 1966

Rate, time, and method of application	Year	None	P	K	PK	Effect of fertilizer	
						+P	+K
				(Pounds per acre)			
1. P, 132 lb./acre	1	8.67	18.97	5.50	13.70	+ 9.25	−4.22
K, 747 lb./acre	2	9.67	16.77	8.82	15.98	+ 7.13	− .82
(Incorporated into	3	9.57	17.98	10.22	16.16	+ 7.18	− .58
the seedbed)	4	11.89	20.80	14.04	22.09	+ 8.48	+1.72
	Total	39.80	74.52	38.58	67.93	32.04	−3.90
2. P, 264 lb./acre	1	8.03	21.50	4.67	18.10	+13.45	−3.38
K, 747 lb./acre	2	10.38	19.68	8.18	16.91	+ 9.01	−2.48
(Incorporated into	3	9.85	21.82	10.29	21.17	+11.42	− .10
the seedbed)	4	12.34	21.81	13.61	24.45	+10.16	+1.96
	Total	40.60	84.81	36.75	80.63	44.04	−4.02
3. P, 132 lb./acre	1	7.68	17.15	7.74	14.36	+ 8.04	−1.36
K, 374 lb./acre[a]	2	10.33	18.42	11.15	18.39	+ 7.66	+ .40
(Topdressed in	3	9.49	17.38	10.69	17.44	+ 7.32	+ .63
spring after	4	10.78	18.34	15.80	21.59	+ 6.68	+4.14
seeding)	Total	38.28	71.29	45.38	71.78	29.70	+3.81
4. P, 33 lb./acre	1	8.91	11.36	9.11	13.05	+ 3.20	+ .94
K, 187 lb./acre	2	10.72	18.10	11.21	17.69	+ 6.90	+ .04
(Topdressed before	3	9.77	20.00	9.32	20.10	+10.50	− .18
growth each	4	13.85	22.14	12.71	23.68	+ 9.63	+ .20
spring)	Total	43.25	71.60	42.35	74.52	30.23	+1.00
5. P, 33 lb./acre	1	8.33	9.37	6.78	8.95	+ 1.60	− .98
K, 187 lb./acre	2	10.80	18.58	10.39	17.96	+ 7.68	− .52
(Topdressed after	3	9.43	19.60	9.70	18.36	+ 9.42	− .48
first cut each	4	12.60	23.64	13.92	24.40	+10.76	+1.04
year)	Total	41.16	71.19	40.79	69.67	29.46	− .94
6. P, 16.5 lb./acre	1	8.78	10.23	8.80	10.04	+ 1.34	− .08
K, 93.5 lb./acre	2	10.46	14.80	10.29	15.91	+ 4.98	+ .47
(Topdressed before	3	8.57	15.99	9.85	15.69	+ 6.63	+ .49
growth each	4	12.72	20.49	12.62	21.66	+ 8.40	+ .54
spring)	Total	40.53	61.51	41.56	63.30	21.35	+1.42
7. P, 33 lb./acre	1	8.38	9.55	9.10	9.03	+ .55	+ .10
K, 187 lb./acre	2	11.12	17.01	11.29	17.96	+ 6.28	+ .56
(Topdressed after	3	10.29	18.63	11.03	18.03	+ 7.67	+ .07
last cut each	4	13.49	23.74	13.45	22.21	+ 9.50	− .78
year)	Total	43.28	68.93	44.87	67.23	24.00	− .05

[a] A second application of K, 374 pounds per acre, was made in the spring of 1965, the third year of production.

pound-per-acre rate of topdressed P, 8.9 pounds per acre more P was removed when compared with the 16.5-pound-per-acre rate of topdressed P. There was very little difference among the other topdressing treatments. Less total K was removed where the fertilizer was incorporated because of the damage to the stand at the time of establishment. When K was applied in two applications (Treatment 3) the amount removed did not differ significantly from that removed from plots receiving the

Table 6. — Potassium, Pounds per Acre, in Alfalfa Hay Following Application of P and K at Different Times and Rates at Elwood, Illinois, 1963 Through 1966

Rate, time, and method of application	Year	None	P	K	PK	Effect of fertilizer	
						+P	+K
				(Pounds per acre)			
1. P, 132 lb./acre	1	105.9	124.4	92.0	190.1	+ 58.3	+ 25.9
K, 747 lb./acre	2	112.9	115.7	142.1	211.5	+ 36.1	+ 62.5
(Incorporated into	3	101.3	122.9	170.7	194.2	+ 22.6	+ 70.4
the seedbed)	4	113.8	121.6	166.7	195.5	+ 18.3	+ 63.4
	Total	433.9	484.6	571.5	791.3	+135.3	+222.2
2. P, 264 lb./acre	1	101.4	126.7	77.5	211.0	+ 79.4	+ 30.2
K, 747 lb./acre	2	121.3	122.4	133.4	196.6	+ 32.2	+ 43.2
(Incorporated into	3	115.8	138.1	168.0	203.1	+ 28.7	+ 58.6
the seedbed)	4	121.8	118.5	170.1	177.5	+ 2.0	+ 53.6
	Total	460.3	505.7	549.0	788.2	+142.3	+185.6
3. P, 132 lb./acre	1	95.3	120.0	127.4	173.7	+ 35.5	+ 42.9
K, 374 lb./acre[a]	2	118.3	123.1	162.4	202.6	+ 22.5	+ 61.8
(Topdressed in	3	109.9	129.4	199.3	260.0	+ 40.1	+110.0
spring after	4	94.5	101.2	201.5	198.9	+ 2.0	+102.4
seeding)	Total	418.0	473.7	690.6	835.2	+100.1	+317.1
4. P, 33 lb./acre	1	105.9	111.0	129.8	166.9	+ 21.1	+ 39.9
K, 187 lb./acre	2	119.4	132.5	156.8	209.6	+ 33.0	+ 57.2
(Topdressed before	3	113.3	127.2	173.4	246.0	+ 43.2	+ 89.4
growth each	4	101.8	129.6	170.9	224.8	+ 40.8	+ 82.2
spring)	Total	440.4	500.3	630.9	847.3	+138.1	+268.7
5. P, 33 lb./acre	1	95.9	98.0	82.9	101.0	+ 10.1	− 5.0
K, 187 lb./acre	2	110.0	140.7	146.3	195.5	+ 40.0	+ 45.6
(Topdressed after	3	101.9	129.2	151.6	202.3	+ 39.0	+ 61.4
first cut each	4	108.8	121.8	200.9	220.0	+ 16.0	+ 95.2
year)	Total	416.6	489.7	581.7	718.8	+105.1	+197.2
6. P, 16.5 lb./acre	1	102.5	106.3	124.3	124.8	+ 2.2	+ 20.2
K, 93.5 lb./acre	2	120.3	120.0	140.3	176.3	+ 17.8	+ 38.2
(Topdressed before	3	106.0	124.3	150.7	172.4	+ 20.0	+ 46.0
growth each	4	117.3	115.5	149.8	192.8	+ 20.6	+ 54.9
spring)	Total	446.1	446.1	565.1	666.3	+ 60.6	+159.3
7. P, 33 lb./acre	1	103.0	112.4	111.2	108.9	+ 3.6	+ 2.4
K, 187 lb./acre	2	120.7	136.0	153.2	186.0	+ 24.0	+ 41.2
(Topdressed after	3	121.7	136.9	156.4	195.9	+ 27.4	+ 46.8
last cut each	4	119.1	112.0	166.1	186.6	+ 6.7	+ 60.8
year)	Total	464.5	497.3	586.9	677.4	+ 61.7	+151.2

[a] A second application of K, 374 pounds per acre, was made in the spring of 1965, the third year of production.

same total amount over a four-year period. However, where annual applications were made, there was greater recovery of K when the application was made in the spring compared with applications after the first or third cuttings.

The weighted average effects of P and K applications on the percent of P and percent of K in the hay over the four-year period are given in Tables 7 and 8. Phosphorus content was increased from 0.14 percent to

Table 7. — Percent Phosphorus[a] in Alfalfa Hay Following Application of P and K at Different Times and Rates

Rate, time, and method of application	None	P	K	PK	Effect of fertilizer	
					+P	+K
			(Percent)			
1. P-132, K-747 lb./acre incorporated	.14	.20	.14	.19	+.06	.00
2. P-264, K-747 lb./acre incorporated	.15	.23	.14	.22	+.08	−.01
3. P-132, K-374 lb./acre topdressed in spring once[b]	.14	.20	.15	.19	+.05	.00
4. P-33, K-187 lb./acre topdressed in spring annually	.15	.21	.14	.19	+.06	−.02
5. P-33, K-187 lb./acre topdressed after first cut annually	.15	.20	.14	.19	+.05	−.01
6. P-16.5, K-93.5 lb./acre topdressed in spring annually	.14	.18	.14	.18	+.04	.00
7. P-33, K-187 lb./acre topdressed after third cut annually	.15	.20	.15	.18	+.04	−.01

[a] Percent phosphorus $= \left(\frac{\text{lb. P in hay, 1963-1967}}{\text{lb. hay, 1963-1967}} \times 100\right)$.

[b] A second application of K, 374 pounds per acre, was made in the spring of 1965, the third year of production.

Table 8. — Percent Potassium[a] in Alfalfa Hay Following Application of P and K at Different Times and Rates

Rate, time, and method of application	Nutrient applied				Effect of fertilizer	
	None	P	K	PK	+P	+K
			(Percent)			
1. P-132, K-747 lb./acre incorporated	1.58	1.23	2.13	2.23	−.08	+.73
2. P-264, K-747 lb./acre incorporated	1.66	1.35	2.16	2.16	−.15	+.65
3. P-132, K-374 lb./acre topdressed in spring once[b]	1.56	1.34	2.25	2.24	−.12	+.80
4. P-33, K-187 lb./acre topdressed in spring annually	1.52	1.44	2.09	2.21	+.02	+.67
5. P-33, K-187 lb./acre topdressed after first cut annually	1.50	1.38	2.05	1.97	−.10	+.57
6. P-165, K-93.5 lb./acre topdressed in spring annually	1.58	1.39	1.94	1.87	−.13	+.42
7. P-33, K-187 lb./acre topdressed after third cut annually	1.57	1.41	1.92	1.85	−.12	+.40

[a] Percent potassium $= \left(\frac{\text{lb. K in hay, 1963-1967}}{\text{lb. hay, 1963-1967}} \times 100\right)$.

[b] A second application of K, 374 pounds per acre, was made in the spring of 1965, the third year of production.

0.20 percent by fertilizer P. Fertilizer K increased the K content of forage from 1.47 percent to 2.08 percent. Application of K had little or no effect on the P content of the hay. The application of P reduced the average K content from 1.57 percent to 1.38 percent where no K had been applied, but had no effect on K content where K fertilizer had been applied. More hay and forage K were removed where P was applied, and K was a limiting factor on plots which received no K fertilizer. When compared with 132 pounds per acre of P, 264 pounds per acre increased the percent of P in the forage from 0.19 to 0.22. There was little difference in P content among topdressing treatments, except for the 16.5- and 33.0-pound-per-acre rates of P. The higher rate resulted in a P content of 0.20 percent, compared with 0.18 percent for the lower rate. The K content was increased more in Treatment 3, 374 pounds per acre of K topdressed in the spring in 1963 and 1965, than in Treatment 4 where 187 pounds per acre of K was applied each spring. Spring-applied K increased the K concentration more than applications made after the first and third cuttings. The increase in K content was also less at the lower rate of K.

Phosphorus Uptake From Topdressings

Since yields and P and K contents were determined at each cutting, it was possible to determine the yield response and uptake in the crop immediately following an initial application. The effect of 33 pounds per acre of topdressed P in early spring on alfalfa yield and P content is presented in Table 9. Table 10 shows yield and P content in the second and third cuttings, where a similar amount of P was applied after the first cutting. Table 11 shows the effect of topdressing 33 pounds per acre of P following the third cutting in the first production year. There was an increase in yield and percent of P in the forage in the cutting imme-

Table 9. — Response of Alfalfa to a Topdressing of P Before Growth, April 6, 1963, the First Year of Production (P, 32 Pounds per Acre)

	Date of cutting, 1963		
P	June 3	July 11	August 21
		(Yield, tons per acre)	
+	2.56	.72	.34
−	2.13	.70	.39
		(Percent of P)	
+	.19	.18	.19
−	.16	.16	.17

Table 10. — Response of Alfalfa to Topdressing of P After the First Cutting, June 3, 1963 (P, 32 Pounds per Acre)

	Date of cutting, 1963		
P	June 3	July 11	August 21
		(Yield, tons per acre)	
+	1.77	.79	.45
−	1.74	.70	.30
		(Percent of P)	
+	.16	.18	.22
−	.16	.15	.16

(Rainfall June 3 to July 11, 3.7 inches)

Table 11. — Response of Alfalfa to a Topdressing of P After the Third Cutting, August 21, 1963, the First Year of Production (P, 32 Pounds per Acre, Second Year of Production Data)

	Date of cutting, 1964		
P	May 23	July 15	August 28
		(Yield, tons per acre)	
+	1.97	1.37	.92
−	1.61	1.18	.82
		(Percent of P)	
+	.27	.22	.19
−	.18	.18	.17

(Rainfall Aug. 21 to Nov. 17, 1963, 1.48 inches)

diately following application. This was remarkable, especially where the topdressings were made after the first and third cuttings in 1963, since rainfall was very low following these applications. Alfalfa can absorb nutrients from the soil surface even under somewhat dry conditions and this is in agreement with observations of other researchers cited earlier.

Trends in Soil Test Values

Trends in soil test values over an eight-year period were followed in plots where the nutrients were incorporated into the seedbed (Treatments 1 and 2). The annual average soil test values, P_1, K, and pH of soil samples taken after each cutting each year, in most cases, are given in Table 12. Samples were taken on August 19, 1962, before the P and K were applied, so only variation among soil samples is present. Treatments in the first four columns were from within main plots where 132 pounds per acre of P was applied and treatments in columns five through eight were from within main plots where P was applied at 264 pounds per acre.

Table 12. — Soil Test Values Over an Eight-Year Period for P, K, and pH on Plots Receiving Different Fertilizer Treatments; Average of Three Sampling Dates

Year	Pounds per acre of nutrient incorporated							
	None	P-132	K-747	P-132 K-747	None	P-264	K-747	P-264 K-747
				Available soil P, lb./A.				
1962[a]	12.0	10.0	10.0	10.0	12.0	12.0	12.0	11.0
1963	14.0	91.0	23.0	119.0	15.3	161.0	21.0	256.0
1964	11.0	62.7	15.7	60.0	14.0	104.7	17.3	186.0
1965	9.3	59.3	13.3	59.3	10.3	132.3	16.0	146.0
1966	8.0	30.0	10.3	45.7	8.3	87.0	12.0	78.7
1967	8.0	31.3	10.7	47.0	9.0	74.7	11.0	86.7
1968	7.7	20.0	9.0	31.0	9.3	52.0	9.0	62.0
1969	7.7	15.3	9.0	21.7	7.7	35.0	9.0	43.0
				Exchangeable soil K, lb./A.				
1962[a]	223	226	210	211	238	236	224	246
1963	181	176	705[b]	725[b]	189	178	728[b]	702[b]
1964	163	166	556	506	173	164	676	580
1965	132	131	435	322	137	128	462	350
1966	140	117	266	224	121	121	326	210
1967	152	114	198	163	117	113	241	165
1968	124	124	170	136	130	125	187	152
1969	124	111	169	132	119	116	164	138
				Soil acidity, pH				
1962[a]	6.1	6.0	6.0	5.9	6.0	6.1	6.0	6.1
1963	5.8	5.9	5.6	5.4	5.6	5.7	5.3	5.6
1964	6.0	6.1	5.8	5.8	5.8	5.9	5.7	5.6
1965	6.0	6.0	5.8	5.6	5.9	5.9	5.7	5.6
1966	6.1	6.1	5.9	5.7	6.0	5.9	5.8	5.8
1967	6.2	6.0	6.0	5.6	6.0	5.9	5.8	5.7
1968	6.0	5.9	5.7	5.5	5.8	5.7	5.7	5.5
1969	6.1	6.0	5.7	5.6	6.0	5.7	5.7	5.6

[a] Samples were taken before the fertilizer treatments were applied, but after four tons per acre of lime was incorporated.

[b] One sampling date only.

The values shown in columns 1 and 5 are from different sets of plots which received no fertilizer, and observed differences are caused by variation among soil samples. Likewise, values shown in columns 3 and 7 are from different sets which received 747 pounds per acre of K and again the differences are caused by sampling variation.

Trends in soil P and K values were studied by fitting three different regression equations to observations.

$$[1] \quad y = a + bx$$

$$[2] \quad y = a + bx + cx^2$$

$$[3] \quad \log y = a + bx$$

where y = pounds per acre of soil P or K; and x = years after 1962.

Table 13. — Coefficients of Determination Measured With Three Regression Models Where Time (x = Number of Years After Incorporation of Nutrient Into the Soil) Is the Independent Variable and Soil Test K and P_1 Are Dependent Variables Within Fertility Treatments

Nutrients added (lb./a)	Regression models		
	$y=a+bx$	$y=a+bx+cx^2$	$\log y=a+bx$
	Soil test K		
None	.32	.35	.33
P, 132	.55	.66	.52
K, 747	.84	.94	.87
P, 132; K, 747	.81	.97	.90
None	.56	.73	.54
P, 264	.50	.66	.49
K, 747	.88	.95	.92
P, 264; K, 747	.79	.95	.87
	Soil test P_1		
None	.56	.71	.62
P, 132	.78	.81	.86
K, 747	.72	.88	.79
P, 132; K, 747	.77	.84	.86
None	.65	.76	.67
P, 264	.76	.76	.78
K, 747	.82	.86	.85
P, 264; K, 747	.76	.79	.76

With [1] the assumption is made that the rate of change in the soil test value was constant throughout the eight-year period. With [2] the assumption is made that the slope changes at a constant rate throughout the eight-year period, and with [3] it is assumed that the rate of change is proportional to the level of the nutrient. Coefficients of determination for each model are shown in Table 13. For soil test K values equation [2] is best fitting. An "F" test showed the quadratic component either significant or highly significant in seven out of eight cases. For soil test P values the same model gave the best fit where no P was added to the soil, and in all four cases the quadratic component was statistically significant. However, where fertilizer P had been incorporated into the soil there was not much difference in the R^2 values between [2] and [3].

Following P application there has been a rapid decline in soil test P, and the rate of decline has been nearly constant over time. The rate of decline where only 132 pounds per acre of P was applied is beginning to level off, but where P at 264 pounds per acre was applied the rate of decline is largely linear. On check plots the P soil test decreased with time, but seems to have stabilized at a value of about 8 pounds per acre. In most cases the soil test P was somewhat higher where 747 pounds per acre of K was applied.

Following K application there also has been a very rapid decline in the soil test K, and the rate of decline is decreasing as values approach those of plots that received no K. Where 132 pounds per acre and 264 pounds per acre of P have been applied, the K test is slightly lower in most cases. This may be caused by greater removals of K in the hay as a result of response to P fertilization. In the first four years of the experiment there was 106 pounds per acre more K removed from plots that received P than from those that did not.

The observed soil test pH values were rather low for alfalfa, but they have been remarkably stable. The highest average value, pH 6.02, was observed at the beginning of the experiment in 1962 and the lowest value, pH 5.61, was observed the following year. Values in the remaining years ranged from 5.72 in 1968 to 5.91 in 1966. Both P and K had only slight effects on the pH. Without P the average pH was 5.83 and with P it was reduced to 5.77. Without K the average pH was 5.93 and with K it was 5.67. The increase in the P_1 values caused by K applications may have been caused by the change in pH.

Discussion

The primary objective of this experiment was to compare alfalfa yields when fertilizer was incorporated into the seedbed with yields resulting from topdressings after establishment, and to compare annual topdressings with less frequent applications when the total amount remained constant. Two rates of fertilizer incorporated and two different rates topdressed were also compared. The magnitude of the responses to P and K applied in the various treatments is summarized in Tables 14 and 15. The least significant difference (L.S.D.) shown is for comparing magnitudes of the responses. The precision in the experiment does not permit showing significant differences in the magnitude of responses. Differences observed will be discussed as observations that may or may not be caused by treatment.

The higher rate of P, 264 pounds per acre, incorporated into the seedbed resulted in a greater hay yield, more P and K in the hay, a higher P content, and a lower K content than where only 132 pounds per acre was incorporated. Incorporation of 747 pounds per acre of K into the soil resulted in a reduction in hay yields, especially in the first two years of production, because of damage to seedlings during the establishment period. In the last three years, however, yields were increased, but not as much as where K was topdressed the first and third years of production. In the latter case, the K content was somewhat higher than where the fertilizer was incorporated.

Table 14. — Response to Phosphorus Applications During a Four-Year Period, 1963 Through 1966, and the Following Three Years After Fertilizer Applications Were Discontinued

	P, 264 lb./a incorporated, 1962	P, 132 lb./a incorporated, 1962	P, 132 lb./a topdressed, 1963	P, 33 lb./a topdressed in spring annually	P, 33 lb./a topdressed after first cut annually	P, 16.5 lb./a topdressed in spring annually	L.S.D., 5%
			1963 through 1966				
Increase in hay yield, ton/A.	5.24	4.53	3.81	3.54	3.96	2.94	1.87
Increase in P removed, lb./A.	44.04	32.04	29.70	30.23	29.46	21.35	8.74
Increase in K removed, lb./A.	142.3	135.3	100.1	138.1	105.1	60.6	55.84
Change in percent P in hay	+.080	+.055	+.052	+.055	+.050	+.038	.015
Change in percent K in hay	−.16	−.08	−.12	+.01	−.10	−.13	.15
			1967 through 1969				
Increase in hay yield, tons per acre	2.42	2.12	1.33	2.76	1.90	1.00	1.47

Table 15. — Response to Potassium Applications During a Four-Year Period, 1963 Through 1966, and the Following Three Years After Fertilizer Applications Were Discontinued

	K, 747 lb./a (P, 264 lb./a) incorporated, 1962	K, 747 lb./a (P, 132 lb./a) incorporated, 1962	K, 747 lb./a (P, 66 lb./a) topdressed, 1963+1965	K, 187 lb./a (P, 33 lb./a) topdressed, in spring annually	K, 187 lb./a (P, 33 lb./a) topdressed after first cut annually	K, 93.5 lb./a (P, 16.5 lb./a) topdressed in spring annually	L.S.D., 5%
			1963 through 1966				
Increase in hay yield, ton/A.	−.82	−.54	+1.42	+1.22	+.36	+.78	1.87
Increase in K removed, lb./A.	185.6	222.2	317.1	268.7	197.2	159.3	55.84
Increase in P removed, lb./A.	−4.02	−3.90	+3.81	+1.00	−.94	+1.42	+8.74
Change in percent K in hay	+.65	+.73	+.80	+.67	+.57	+.42	.15
Change in percent P in hay	−.004	−.006	−.002	−.010	−.007	−.004	.015
			1967 through 1969				
Increase in hay yield, tons per acre	+.60	+.86	+1.85	+.72	+1.66	+.93	1.47

Where 132 pounds per acre of P was topdressed only once at the beginning of the first year of production, yield was slightly higher than where the same total amount of fertilizer was applied each year for four years in equal increments. However, in the last three years of production, the response to P was twice as large where the annual applications had been made the four previous years. Somewhat more P and K were removed where there were annual applications, and the percent of P was increased more and the percent of K was depressed less.

Where the phosphorus was applied after the first cutting each year, rather than in the spring prior to growth, the yield of hay in the first four-year period was slightly greater. However, in the last three years of production, hay yield was substantially less. There was less P and K removed and the changes in P and K contents were less where topdressing of P was made after the first cutting compared with spring application. Response to K was greater in hay yields where it was applied in the spring rather than after the first cutting. The amount of K in hay was also greater where the K was applied in the spring, and the increase in the K content was greater when the K was applied in the spring. However, in the last three years of production, the largest increase in yield caused by K was when the application was made after the first cutting.

Lower rates of P and K, 16.5 and 93.5 pounds per acre respectively topdressed in the spring, resulted in a smaller increase in yield for both P and K than higher rates. The increase in P and K in hay and the percent of P and K were less where the smaller amounts of fertilizer were used. Likewise, response to P in the last three years was smaller than where the higher rate was used. Residual response to K at the lower rate of application was greater than at the higher rate. This is probably caused by sampling variability.

Where P was applied each year after the last cutting, the yield response was about the same as where it was applied before growth in the spring. The increase in the amount of P in the hay was 4.4 pounds per acre less. The increase in the amount of K removed in the hay was strikingly less, 74.4 pounds per acre. The increase in the content of P in the forage was smaller when the fertilizer was applied in the fall. There was a reduction in percent of K which was not observed where the P was applied in the spring. The residual effect in the last three years was somewhat greater where the P was applied after the last cutting each year for the first four years of the study. Where K was applied after the last cutting each year, the increase in yield was somewhat less than where it was applied in the spring. The increase in the amount of K removed was considerably lower when the K was applied in the fall at 93.5 pounds per acre. The influence of K on the amount of P removed was slight in both cases. The increase in K content was less for fall applications than for spring applications. The P content was depressed only slightly in both cases. Residual response to K in the last four years was not large, but it was twice as large where the K was applied in the fall rather than in the spring.

Summary and Conclusions

The effect of topdressings of P and K fertilizers on established alfalfa were compared with similar amounts of fertilizer incorporated into the seedbed. There were good responses to both P and K from topdressed fertilizer, but they were not as large as those from incorporated fertilizer. Annual topdressing of fertilizer was also compared with one application in four years in the case of P and two applications in four years in the case of K. In the first four years of production annual applications gave a smaller yield response than less frequent applications. However, in the next three years when no fertilizer was applied, response to the residual P in annual applications was twice as large as to the single application. In the case of K the opposite was true. There appears to be no advantage to annual topdressings of P and K over less frequent applications.

Among annual applications, an early spring application about the time growth was starting was compared with applications made after the first and third cuttings. The response to P was slightly greater and the response to K was less in a spring application than in an application made after the first cutting. The responses to the spring application were somewhat greater for both P and K than those found when the application was made after the third cutting. Response to residual fertilizer applications in the last three years was greater where fertilizer was applied after the third cutting. A reduced rate of both P and K in the spring gave smaller increases in yield in all cases, except for K in the last three years when residual effects of fertilizer were being studied.

Where no fertilizer was applied, an annual average of 10 pounds per acre of P and 110 pounds per acre of K were removed in the hay each year from 1963 through 1966. These amounts were increased to 18 pounds per acre of P and 149 pounds per acre of K where each nutrient was applied without the other. Where both P and K were applied, the removal of P was almost identical, but K removal was increased to 190 pounds per acre. Even where K was not applied, the removal of K was increased 12 pounds per acre annually where P was applied. There were no significant differences observed in the amounts of P and K removed in the hay among the comparisons made in this experiment.

The application of P fertilizer increased the average percent P in hay in the initial four-year period from 0.14 percent to 0.20 percent, and the application of K increased the average percent K from 1.47 percent to 2.08 percent. The application of P reduced the percent of K in the hay 0.10 percent and the application of K reduced the percent of P in the hay 0.01 percent.

The alfalfa plant obtained both P and K almost immediately after they were applied as topdressings, even under rather dry conditions.

Literature Cited

HANWAY, J. G., G. STANFORD, AND H. R. MELDRUM. 1953. Effectiveness and recovery of Phosphate and Potash Fertilizers Topdressed on Meadow. Soil Sci. Soc. Amer. Proc. 17:378-382.

JACKSON, M. L. 1958. Soil Chemical Analysis. Prentice Hall Inc., Englewood Cliffs, N.J., p. 336.

KRESGE, C. B. AND S. E. YOUNTS. 1962. Effect of Various Rates and Frequencies of Potassium Application on Yield and Chemical Composition of Alfalfa and Alfalfa-Orchardgrass. Agron. Jour. 54:313-316.

LAVERTY, J. C. 1963. A Modified Procedure for the Determination of Phosphorus in Soil Extracts. Soil Sci. Soc. Amer. Proc. 27:360-361.

LAWTON, K., M. B. TESAR, AND B. KAWIN. 1954. Effect of Rate and Placement of Superphosphate on the Yield and Phosphorus Absorption of Legume Hay. Soil Sci. Soc. Amer. Proc. 18:428-432.

MARKUS, D. K. AND W. R. BATTLE. 1965. Soil and Plant Responses to Long-Term Fertilization of Alfalfa (*Medicago sativa* L.). Agron. Jour. 57:613-616.

SMITH, G. F. 1965. The Wet Chemical Oxidation of Organic Compositions Employing Percloric Acid. Frederick Smith Chemical Co., Inc., Columbus. Sec. 6, p. 55.

STIVERS, R. K. AND A. J. OHLROGGE. 1952. Influence of Phosphorus and Potassium Fertilization of Two Soil Types on Alfalfa Yield, Stand, and Content of These Elements. Agron. Jour. 44:618-621.

TERMAN, G. L., E. C. DOLL, AND J. A. LUTZ, JR. 1960. Rate, Source, Time, and Method of Applying Phosphates for Alfalfa and Legume-Grass Hay and Pasture. Agron. Jour. 52:261-264.

WOODHOUSE, W. W., JR. 1956. Effect of Placement and Rate of Phosphate, Potash, and Limestone on the Growth of Alfalfa and Lespedeza. Soil Sci. Soc. Amer. Proc. 20:15-18.

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